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Fire History in Mixed-Conifer Forests of the Sacramento Mountains, Southern New Mexico

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INTRODUCTION

Episodic fire was an integral component of many forest communities of the western United States prior to widespread settlement by non-native peoples (Wright and Bailey 1982, Swetnam and Baisan in press). This study is an effort to reconstruct past spatial and temporal patterns of fire events in mixed-conifer stands of the Sacramento Mountains of southern New Mexico prior to and since widespread settlement of this area. The mixed conifer forests of the Sacramento Mountains were heavily logged in the early part of the 20th century (Glover 1984), and we hypothesize that current disturbance regimes, particularly fire and insect outbreaks, differ significantly from those of past centuries. The fire histories developed by this study include data on past fire frequency, timing, seasonality, and spatial patterning. These data are useful not only for understanding the role of fire in ecosystem dynamics in the mixed-conifer forests of the Sacramento Mountains, but also provide essential information necessary for land and fire management activities in this area. This study is part of an integrated effort among several Rocky Mountain Station investigators and other scientists to examine long-term disturbance processes and stand dynamics in the Sacramento Mountains.

METHODS

Site selection

In 1994, we collected samples from 115 trees at 8 sites in five different locations in the Sacramento Mountains (table 1, figure 1). In 1995, we collected samples from 87 trees at 4 additional sites in the Sacramento Mountains and at 5 locations along an elevational gradient at a location in the White Mountains to the north (table 1a). Sampling occurred during the summers and falls of 1994 and 1995. Sites were chosen to represent a range of elevations, moisture regimes, and forest community types (Dick-Peddie 1993, Alexander et al. 1984) within the mixed-conifer forest. Many of the sites were at or near sites sampled by other Station scientists for which a variety of data exist on wildlife use, stand structure and dynamics, and insects and diseases.

Most of the samples we have collected were sections from fire-scarred stumps, logs, and snags, and some partial sections and cores from living trees. Sampling of fire-scarred material was designed to obtain an inventory of fire events for a given site that is as long and complete as possible (Swetnam and Baisan in press). Because fire-scarred trees do not occur or persist in a spatially predictable way, our samples were collected from areas which were variable in size, although all sites were less than approximately 50 ha in size. Samples were collected by directed sampling of trees with long scar records visible in fire-formed cat faces. Most of the trees recording fires were ponderosa pine (Pinus ponderosa) or southwestern white pine (Pinus strobiformus), although a few were Douglas-fir (Pseudotsuga menziesii). We also collected cores from older living trees found in the same vicinity as the fire-scarred material. The oldest trees we located were around 400 years of age. These cores are used to aid in crossdating of remnant (dead) material and to pinpoint when logging occurred in these areas based upon dates of growth releases evident in the tree-ring series.

Laboratory methods

All samples have been prepared and surfaced at this time. Many of the fire-scarred remnant samples were highly decayed and required gluing and other preparatory work before surfacing. A finely sanded surface was put on all samples, first using a hand planer and then sanding with a belt sander with progressively finer sandpaper to 320 or 400 grit. Fine sanding is necessary to see cell structure within annual rings and at fire scar boundaries.

Ring series and fire scars on all samples collected for this study are crossdated using standard dendrochronological procedures (Stokes and Smiley 1968, Swetnam et al. 1985). Ring width index chronologies from the Cloudcroft area, available from the International Tree-Ring Data Bank, National Geophysical Data Center, Boulder, Colorado, provide dating control for remnant material (Brown and Swetnam 1994). To date, all trees in all sites have been examined at least once for crossdating suitability. Most samples have been fully crossdated and the results from the following sites are described below: all samples from the 1994 sites - James Ridge, Delworth, Sunspot, Monument Canyon, Monument Canyon Upper, Cathey Canyon Vista, Cosmic Ray Observatory, and Peake Canyon; and samples from four of the 1995 sites - Buck Mountain, Water Canyon, Fir Campground, and Sunspot Pines. Of the 1994 sites, James Ridge is the lowest and most xeric site collected. Delworth is a site intermediate in elevation and moisture regime. Sunspot is the wettest and one of the highest elevation sites we collected (table 1). Peake Canyon is also intermediate in elevation and moisture; Cathey Canyon is high elevation but relatively dry; Cosmic Ray Observatory is high elevation and intermediate moisture regime; the two Monument Canyon sites are at intermediate elevations and are relatively dry. Of the 1995 sites, Fir Campground is the highest elevation and relatively mesic; Water Canyon is at intermediate elevation and wet; Sunspot Pines is at high elevation and is dry; Denny Hill is the lowest elevation and the driest. The Buck Mountain sites include a range of elevations and moisture regimes.

Once crossdating of tree rings series on samples at a site is assured, dates are then assigned to fire scars and any other evidence of fire or injury seen in the ring series. Notes also include the position of a scar within the annual ring when this can be determined.

Analysis

Fire scar dates and seasonality are compiled into fire chronologies for each site using program FHX2 (H.D. Grissino-Mayer, unpublished; Swetnam and Baisan in press). FHX2 computes a variety of central tendency statistics for fire chronologies and compiles descriptive statistics for scar positions.

RESULTS AND DISCUSSION

Samples from 1994

James Ridge

James Ridge is the warmest, driest site we collected in 1994, and was classified as the Pseudotsuga menziesii/Quercus undulata habitat type. Most of the samples collected at James Ridge were from ponderosa pines. The fire chronology for the James Ridge site is shown in figure 2. In the top portion of the figure, time spans recorded by rings of individual trees are shown as horizonal lines, with fire scars or other injuries noted by triangles at the dates they were recorded. Dates in the bottom part of the figure are those years when the sample depth (number of trees recording a particular year) is greater than three trees and the fire index (proportion of trees recording a fire scar relative to the sample depth) is greater than or equal to 25% of trees collected. In general, trees at James Ridge were young, with very open and complacent ring series. In addition, false rings (interannual latewood bands) were present in most years, indicative of seasonal drought stress. Several pith dates on trees at the site fell into the period from the 1740s to 1760s (figure 2), suggesting, in the absence of a larger dataset of stand ages, that a large portion of the trees in the stand established at that time. These trees represent to a certain extent the maximum age structure at this site (Swetnam and Brown

1992) since they were collected to obtain the longest possible fire scar records. Extremely few old living trees were present on the slope, with JAM 6 the only living fire-scarred ponderosa pine we located.

There is agreement between fire scars recorded on different trees at the site. All samples were growing on a moderate to steep, relatively uniform south-to-southeast-facing slope ranging in elevation from 8300 to 8500 feet. The area was cutover near the turn of the century. There was a logging camp at James Canyon with spurs up and down the canyon in 1900; this camp was dismantled in 1903 (Glover 1984). No fire scar dates were recorded on any tree after 1876 (this date was on JAM 1), although there was frequent fire at the site before this. Based upon only those years when fire scars were recorded on 25% or more of the trees growing at the site (years marked in figure 2), the mean fire interval (MFI) and standard deviation for the period 1754 to 1871 was 9 ± 5 years (N = 13 intervals), with a range from 4 to 19 years. Using all scar dates from the first recorded fire at the site in 1712 to the last in 1876, the MFI was 7 ± 4 years (N = 25) with a range from 2 to 17 years.

Fires generally occurred from before the beginning to the middle of the growing season at James Ridge. Owing to the large, open ring series on most samples from James Ridge, scar position within the ring was discernable on just over 85% (82 out of 97 total scar dates) of the fire scars recorded. Of the scars where scar position was apparent, just over 87% occurred in the dormant season between two rings or in the early to middle part of the earlywood. Many of the scars were recorded at a false ring boundary. This is consistent with historic patterns of fire occurrence in this area of the southwest US. Based upon records of fire occurrence, the majority of fires occurred in the late spring and arid fore-summer of May and June, before the monsoon rains start in July and August. Formation of false rings also occurs at this time, when soil moisture depletion causes growth cessation and premature latewood formation. Once the summer rains start and replenish soil moisture, growth of earlywood

cells begins again and continues until latewood formation and ultimately radial growth cessation at the true end of the growing season in August or September (Fritts 1976).

Delworth

The Delworth fire chronology has both longer time series, due to older trees, and fewer fires than James Ridge (figure 3). The Delworth site was somewhat more mesic than James Ridge and was classified as Abies concolor/Quercus gambeli habitat type, with an inclusion of the more mesic Abies concolor/Erigeron eximius habitat type. Owing to the more advanced state of decay of the samples from Delworth, only a few pith dates are recorded. Ring series from Delworth were both less complacent and had many fewer years with false rings than at James Ridge. Samples from Delworth were from ponderosa pine, southwestern white pine, Douglas-fir and two white fir trees. Trees at Delworth were growing on a moderate to steep south to southeast-facing slope between 8380 and 8600 feet in elevation. The surrounding area was railroad logged in the mid-1930s (Glover 1984), and a growth release and scars caused by skidder activity on living trees indicates another episode of logging in 1969.

Delworth is similar to James Ridge in that the fire history ends in the late 1870s, in this case 1879 (figure 3). Based upon only those fire years when scars were recorded on 25% or more of the trees collected at the site (dates in bottom portion of figure 3), the MFI and standard deviation for the period 1773 to 1879 was 16 ± 8 years (N = 9 intervals) with a range from 6 to 31 years. Using all fire dates from the first recorded fire in 1658 to the last in 1879, the MFI was 10 ± 8 years (N = 22 intervals) with a range from 1 to 31 years. These longer intervals are a reflection of the generally more mesic conditions and slightly higher elevation at Delworth than at James Ridge.

Seasonal timing of fires at Delworth was only slightly different than at James Ridge. Owing to tighter ring series, position within the annual ring could be assessed on only about 63% of all fire scars seen (42 out of 67 total scars). Of those where position could be determined, over 92% were early in the

growing season (dormant, early-earlywood, or middle-earlywood) which is very similar to the patterns seen at James Ridge.

An observation from the fire chronologies at Delworth and James Ridge is that many of the same fire years were recorded at both sites, suggesting that there was regional climate control of fire occurrences (Swetnam 1993, Swetnam and Baisan in press). Years recorded on 25% or more of the trees at each site that were common between the two sites were 1773, 1801, 1832, 1842, and 1860. Some of these years and others recorded at one or the other site were also regional fire years known from other mountain ranges in southern New Mexico or Arizona (e.g. Swetnam and Baisan in press). Possible climate relations with regional-scale fire years in the fire chronologies will be explored in more detail after the other sites in this study are analyzed.

Sunspot

This is the wettest of our 1994 sites. It was not logged. We collected samples from 16 trees on gentle westerly slopes between 9200 and 9320 feet in elevation. Samples collected were from ponderosa pine, southwestern white pine and Douglas-fir from Abies concolor/Erigeron eximius and Abies concolor/Acer glabrum habitat types. The canopy of this old growth stand was beginning to fall apart; many of the largest trees had succumbed to root disease and windthrow.

Monument Canyon

This area was never logged. We collected six samples from within the canyon, from about mid-slope up to the canyon rim on a steep west-facing slope between 7920 and 8000 feet in elevation. This site was more mesic than James Ridge but drier than Delworth, and was classified as Pseudotsuga menziesii/Quercus undulata and Pseudotsuga menziesii/Quercus gambeli habitat types. Samples collected were from ponderosa pine, southwestern white pine, and Douglas-fir; several of the pines had recently been killed by bark beetles.

Monument Canyon Upper

This area adjoined the Monument Canyon site. Most of our samples came from the upper slopes of the canyon and the canyon

rim, from nearly flat to moderately steep mostly east-facing slopes between 8400 and 8620 feet in elevation. Some of this area had been logged, probably in the 1920s or 1930s, and some of our 18 samples came from the edge of an area burned in 1988. The environment here is slightly drier than in the canyon itself but still more mesic than James Ridge. Habitats were classified as Pseudotsuga menziesii/Quercus gambeli and Pseudotsuga menziesii/Quercus undulata.

Peake Canyon

This site was higher and wetter than Monument Canyon. We collected samples from the canyon rim and mostly north- and west-facing slopes in the canyon between 8600 and 9080 feet in elevation. Samples from 20 trees included ponderosa pine, Douglas-fir and southwestern white pine growing in Abies concolor/Quercus gambeli and Abies concolor/Acer glabrum habitat types. This area was logged, probably in the late 1910s and 1920s. Sample #16 from this site is one of our oldest, dating back nearly 400 years, and this ponderosa pine recorded 16 fire events.

Cosmic Ray Observatory

This site and the next two are located relatively close together. We collected samples from six trees from a small area on gentle westerly slopes at about 9420 feet in elevation. This is a high elevation, relatively wet site classified as the Abies concolor/Erigeron eximius habitat type. Samples collected were southwestern white pine and Douglas-fir. This area had been logged.

Cathey Canyon Vista

This area was also logged; a logging camp existed at the confluence of Brown and Cathey Canyons in 1928, and logging probably occurred around that time. We collected samples from the ridge and canyon rim on steep westerly slopes between 9420 and 9550 feet in elevation. This is the highest and coldest of our sites, and one of the wettest. Habitats were classified as Pseudotsuga menziesii/Quercus gambeli and Abies concolor/Acer glabrum. We collected samples from seven trees, all Douglas-fir.

Many of the samples were very decayed, although some of the oldest trees we have are from this site and they are dating relatively well.

Samples from 1995

Fir Campground

We sampled 22 trees at four different areas around Fir Campground. The area immediately around the campground was never logged, and was sampled by Claudia Regan. The areas we sampled were immediately north and northwest of the campground and had been logged, probably around or before 1920. Area 1 included samples 1 through 6 and was located on a gentle (11 degrees) south-facing slope at 8860 feet elevation. We classified the habitat as Psedotsuga menziesii/Quercus gambelii, because there was no Abies concolor present in any size class; most of the regeneration was southwestern white pine and douglas fir. The stand was relatively open and grassy; the gambel oak was very tall.

Area 2 was on a gentle west-facing slope and included samples 7-11. It is located west of the observatory and had apparently been logged in two phases. We classified this habitat as Abies concolor/Quercus gambelii. This area was near some large power lines for which some trees had been cut more recently. Several of the samples from this area were too decayed to be crossdated.

Area 3 was located just below the observatory to the east in a shallow draw, and included samples 12-14. Some aspen was present in the understory, as was Acer glabrum. Though the understory was sparse, this habitat may be classified as Abies concolor/Acer glabrum.

Area 4 included samples 15 through 22 and was located on and around a ridge southwest of the observatory on relatively steep (23 degrees), mostly west-facing slopes at 8700 feet elevation. Most of the canopy trees and stumps were southwestern white pine and a few douglas fir, but most of the regeneration was white fir, so we classified this site as Abies concolor/Quercus gambelii.

The oldest trees we sampled in the Sacramento Mountains came from this site; tree #8 dated to 1532 near the pith, and six other samples dated to the 16th and 17th centuries. Most of the trees sampled were southwestern white pines, mostly stumps; there were no ponderosa pines at this site. See figure 11 for a display of fire dates. In general, fires were more frequent in this area during the 19th century than in centuries before, though the sample depth before 1750 declines considerably. The most recent fire in the area was in 1924, evident only in area 1, and this probably coincided with slash burning associated with logging. All the areas at this site record a fire in 1890. Where seasonality was discernable, we note that fires at Fir Campground were often in the middle early wood, in the mid to early growing season.

Sunspot Pines

We sampled 8 trees at this site, which is located on the south-facing slope just above the 1994 Sunspot oldgrowth site and just below the radio tower at 9200 feet elevation. The slope was moderate (16.5 degrees), and we classified the habitat as Pseudotsuga menziesii/Quercus gambelii. Some of the oaks were very large, reaching the canopy. The area had been logged in at least two phases, and the old landing at the base of the slope is now a meadow. Most of the stumps were ponderosa pine and a few southwestern pine, which make up the canopy today. Most of the young regeneration is douglas fir, though some pines are regenerating. These samples dated very well; two trees had pith dates in the early 17th century. The most recent fire at this site was recorded in 1879; sample #3 recorded 17 fires since 1649 (see figure 12). Some trees in this stand had recently been attacked by bark beetles and some had been killed.

Water Canyon

We sampled 12 trees in two areas at this site, which was one of the wettest. Area 1 was in the oldgrowth stand sampled by Claudia Regan and included samples 1-6. This stand was on a moderate to steep (19 degrees) east-facing slope at 8840 feet elevation; a spring came out of the slope just above the road.

We classified the habitat as Abies concolor/Quercus gambelii; the overstory was entirely douglas fir and white fir, and white fir comprised most of the regeneration.

Area 2 was located on steep (21 degrees) south and southeast-facing slopes below a ridge south of area 1, and included samples 7-12. We classified this habitat as Abies concolor/Acer glabrum because the maple and aspen were regenerating in the understory; other ground cover was sparse. On slopes above the stand, tall aspen were giving way to conifers. White pine was regenerating in this area, but most of the canopy and regeneration was douglas fir and white fir. This area was logged early in this century. Where seasonality was discernable, many of the fires occurred in the middle of the growing season. The most recent fire was dated to 1908. In general more fires were recorded by trees in area 2. The oldest tree we sampled at this site dated to 1629, but most of the samples dated from the mid 18th to early 19th centuries. See figure 13 for fire frequencies.

Denny Hill

This was the lowest elevation, warmest and driest of all the sites we sampled in the Sacramentos. We sampled 16 trees on steep (22 degrees) north to northeast-facing slopes at 7560 feet elevation. This north slope was apparently spared in the fire in 1955 which burned the ridge and surrounding slopes. The burned areas are regenerating to pinon pine and juniper. Mixed conifer forest occurs only on the sheltered and relatively mesic north-facing slope as an isolated stand.

The area was logged early in this century. A few large old ponderosa pines remain in the canopy, but most are dying. Most of the regeneration is douglas fir and white pine, but some ponderosa pine is regenerating. Most of the trees we sampled had been ponderosa pine, a few white pine. We also sampled two junipers which may not be datable due to many false rings. We classified the habitat as Pseudotsuga menziesii/Quercus gambelii grading into Pseudotsuga menziesii/Quercus undulata at the western end of the slope at the 1955 burn edge. Vegetation in

this area was sampled in 1985 for the Lincoln National Forest Habitat Type course.

Most of the samples from this site are not yet crossdated, so there is no figure illustrating fire frequency. They are difficult to date due to many false and missing rings, many fire scars, insect galleries and rot. However, fire seems to have been very frequent here; sample #6 records 23 scars, the most we have found on a single tree in the Sacramento Mountains. Preliminary dates on several samples show establishment dates in the 1680s and 1690s.

Buck Mountain

This site is in the White Mountains north of the Apache Indian Reservation, near the town of Ruidoso. It is located in the Lincoln National Forest, and the White Mountains are contiguous with the Sacramento Mountains. We sampled 29 trees in 5 areas along an elevational transect from 9600 feet to 8000 feet on Buck Mountain. All samples come from mixed conifer forests, but some of the habitats are slightly different from those we collected farther south.

Area 1 included samples 1-5, and was the highest elevation we sampled on Buck Mountain, 9600 feet. The site was on as steep (24.5 degrees) south-facing scree slope. We classified the habitat as Abies concolor/Holodiscus dumosus , though understory was rocky and sparsely vegetated. These trees recorded relatively few fires, the most recent in 1892. There was no sign of historic logging, though these trees were very near the road. All the trees sampled were white pines.

Area 2 included samples 6-8, all of which were ponderosa pines. This area had been logged, probably early in the 20th century. This site was located on a steep (29 degrees) east-facing slope at 9180 feet elevation. The habitat was classified as Abies concolor/Quercus gambelii. Trees from this area recorded considerably more fires than those in area 1, between 8 and 10 per tree.

Area 3 was a long, steep (24 degrees), east-facing slope at 9000 feet elevation, where we found many large fire-scarred

trees. This stand did not appear to have been logged. This area includes samples 9-18, which were ponderosa pines and white pines. The understory was sparse and gambel oak was present, as were many small tufts of Arizona fescue, which led us to believe that this was once a much more open stand. We classified this habitat as Abies concolor/Festuca arizonica, Quercus gambelii phase. Regeneration of douglas fir, white fir and white pine was very dense. The overstory was composed of large old ponderosa pines, but ponderosa pine was not regenerating. Many ponderosa pines were being attacked by bark beetles. Ring patterns of samples 13, 15 and 17 seem to be more sensitive to beetle attacks than to fire. The oldest sample at this site dated to 1668. Numbers of fires recorded per tree were similar to those in area 2, the most recent being in 1925. See table x for fire frequency.

Area 4 was located on the opposite side of the ridge from area 3, on a steep north-facing slope at 8960 feet elevation. This area was much wetter than area 3, and we classified the habitat as Abies concolor/Acer glabrum. Most of the trees in the canopy and in the regeneration were white fir. This site included samples 19-21, all of which were white pines. These trees recorded fewer fires than those in area 3, the most recent in 1888. Sample 19 dated to 1572.

Area 5 was located near Eagle Creek on moderate southwest-facing slopes at 8000 feet elevation. This site includes samples 22-29, all of which were white pines except two. We classified the habitat as Abies concolor/Quercus gambelii. There were many cabins in this area along the creek, and there appears to have been an episode of logging before the cabins were built. We saw signs of spruce budworm in the douglas fir near the creek. These trees recorded fewer fires than area 3, the most recent in 1889. Their ring patterns were generally complacent and did not date as well as those in other areas. Many of the remnant samples were quite rotten. The elevational pattern with fire was different on Buck Mountain than at our Sacramento Mountains sites because the transect ended in the canyon of Eagle Creek. Like the Sacramento

transect, fires were generally less frequent at higher elevations, becoming more frequent at lower elevations. But the lowest elevation site on Buck Mountain showed a decrease in fire frequency from the middle elevations, probably because of the proximity of Eagle Creek, which created a wetter environment more sheltered from wind (figure 14).

Timing of fire years between sites

Many of the same fire years were recorded at more than one site or area in the Sacramento Mountains (figure 10), suggesting that there was regional climate control of fire occurrences (Swetnam 1993, Swetnam and Baisan in press). Some of the more widespread fire years in the Sacramento Mountains were also regional fire years over much of the southwestern U.S. These years include 1748, 1801, 1847, and 1879. Possible climate relations, such as with the El Nino-Southern Oscillation, will be explored in future analyses with the fire chronologies described here.

Scar positions recorded as dormant (before the growing season began in the spring) or early in the earlywood are consistent with historic patterns of fire occurrence in this area of the southwest U.S. Based upon records of fire occurrence, the majority of fires occurred in the late spring and arid fore-summer of May and June, before the monsoon rains start in July and August. Formation of false rings also occurs at this time, when soil moisture depletion causes growth cessation and premature latewood formation. Once the summer rains start and replenish soil moisture, growth of earlywood cells begins again and continues until latewood formation and ultimately radial growth cessation at the true end of the growing season in August or September (Fritts 1976).

SUMMARY

Results so far suggest that there are significant differences in fire frequency between sites in the mixed-conifer zone of the Sacramento Mountains, most likely due to variation in moisture regimes and elevation. Fire frequencies are similar between stands in the White Mountains and those in the Sacramento

Mountains at similar elevations and moisture regimes, but only a few of the actual fire dates are the same. Dramatic changes in fire regimes between the pre-settlement era before the late 1800s and the present suggest that much of ecosystem structure and function related to fire has also changed. This finding should have important implications for management of mixed-conifer forests in the Sacramento Mountains. It is anticipated that the remaining fire chronologies for the Sacramento Mountains will be completed by this spring.

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Table 1. Sacramento Mountains fire history sites and information.

Site	Slope	Aspect	Elev.	HT	Quad	Samples
James Ridge	moderate to steep	S-SE	8300-8500	PSME/ QUUN	Harvey Ranch	3 cores 16 sections; 15 trees, all PIPO
Peake Canyon	flat to steep	N, SW, NW, S, W	8600-9080	ABCO/ QUGA, ABCO/A CGL	Cloudcroft	2 cores, 22 sections; 20 trees; PIPO, PSME, PIST
Sunspot	flat to gentle (14)	W	9200-9320	ABCO/E REX, ABCO/P OLE	Sacramento Peak	8 cores, 13 sections; 16 trees; PIPO, PSME, PIST
Cathey Canyon Vista	steep, 17-31	W, NW	9420-9540	PSME/ QUGA, ABCO/A CGL	Sacramento Peak	7 sections, all PSME
Cosmic Ray Observatory	gentle, 14	W, NW	9420	ABCO/E REX	Sacramento Peak	2 cores, 4 sections; 6 trees, PIST, PSME
Monument Canyon	29-31 steep	W	7920-8000	PSME ~~ABCO~~/ QUUN, PSME/ QUGA	Rogers Ruins	6 sections, 6 trees; PIPO, PIST, PSME
Monument Canyon -- Upper	10-20; flat on ridge, steep on slopes	NE, E SE, W, NE; mostly E	8400-8620	PSME ~~ABCO~~/ QUGA, PSME ~~ABCO~~/ QUUN	Rogers Ruins	2 cores, 20 sections, 17 trees;PSME, PIST, PIPO
Delworth	moderate to steep	S, SE	8380-8600	ABCO/ QUGA, ABCO/E REX	Bluff Springs	14 cores, 15 sections, 28 samples; PSME, PIPO, ABCO, PIST

Table 1a. Sacramento Mountains fire history sites and information.

Site	Slope	Aspect	Elev.	HT	Samples
Fir Campground	moderate to steep	S, W	8700-8900	PSME/QUGA, ABCO/QUGA	22 trees, PIPO, PIST, 1 PSME
Sunspot Pines	moderate	S	9200	PSME/QUGA	8 trees, all PIPO
Water Canyon	steep	E, S	8840, 9000	ABCO/QUGA, ABCO/ACGL	12 trees, PIST and PSME
Denny Hill	steep	N-NE	7560	PSME/QUGA and PSME/QUUN	16 trees; PIPO, PIST, PIED
Buck Mountain 1	steep	S	9600	ABCO/HODU	5 trees; all PIST
2	steep	E	9180	ABCO/QUGA	3 trees; all PIPO
3	steep	E	9000	ABCO/FEAR, QUGA phase	10 trees; PIPO and PIST
4	moderate	N	8960	ABCO/ACGL	3 trees; all PIST
5	gentle	SW	8000	ABCO/FEAR, QUGA phase	8 trees, 3 cores, PIST, PIPO, 1 PSME

Table 2. Mean fire intervals (MFIs) with standard deviations and ranges of intervals for different periods of the fire scar records at sites in the Sacramento Mountains. MFIs, standard deviations, and ranges are in years. Fire intervals used are between all fires recorded on any tree at a site and on only those between years when the sample depth was > 2 trees and the fire percentage of trees scarred for a fire year was ≥ 25% (i.e., those years marked in the middle portion of figures 2 to 8). Note that the period of analysis for Monument Canyon for the ≥ 25% category does not include the interval between 1879 and 1953. Also the period of analysis for Peake for the same category does not include the interval between 1617 and 1685.

Site	% of Trees Scarred	Period	No. of Fire Intervals	MFI ± Std. Dev.	Range
James Ridge	All dates	1712 to 1876	25	7 ± 5	2 to 17
	≥ 25%	1754 to 1871	13	9 ± 5	4 to 19
Monument Canyon	All dates	1822 to 1953	7	18 ± 8	5 to 74
	≥ 25%	1822 to 1879	5	11 ± 5	6 to 17
Mon. Canyon Upper	All dates	1625 to 1953	25	13 ± 6	1 to 74
	≥ 25%	1733 to 1879	12	12 ± 5	4 to 20
Peake	All dates	1601 to 1904	30	10 ± 9	1 to 25
	≥ 25%	1685 to 1904	13	17 ± 11	1 to 34
Delworth	All dates	1658 to 1879	22	10 ± 8	1 to 31
	≥ 25%	1684 to 1879	11	18 ± 8	6 to 31
Cathey Canyon	All dates	1684 to 1923	12	20 ± 14	4 to 51
	≥ 25%	1789 to 1879	4	23 ± 14	10 to 43
Sunspot	All dates	1721 to 1941	14	16 ± 15	2 to 62
	≥ 25%	1748 to 1879	3	44 ± 23	29 to 70
Cosmic Ray Obs.	All dates	1729 to 1945	7	31 ± 28	1 to 72
	≥ 25%	1847 to 1879	1	32	

Figure Captions

Figure1. Map of site locations in the Sacramento Mountains.

1a. Larger scale.

Figure 2. Fire chronology for James Ridge. In the top portion of the figure, time spans recorded by rings of individual trees are shown as horizonal lines, with fire scars noted by triangles at the dates they were recorded. Dates in the bottom part of the figure are those years when the sample depth (number of trees recording a particular year) is greater than three trees and the fire index (proportion of trees recording a fire scar relative to the sample depth) was greater than or equal to 25% of trees collected.

Figure 3. Fire chronology for Monument Canyon. See figure 2 for figure explanation.

Figure 4. Fire chronology for Monument Canyon Upper. See figure 2 for figure explanation.

Figure 5. Fire chronology for Peake Canyon. See figure 2 for figure explanation.

Figure 6. Fire chronology for Delworth. See figure 2 for figure explanation.

Figure 7. Fire chronology for Cathey Canyon. See figure 2 for figure explanation.

Figure 8. Fire chronology for Sunspot. See figure 2 for figure explanation.

Figure 9. Fire chronology for Cosmic Ray Observatory. See figure 2 for figure explanation.

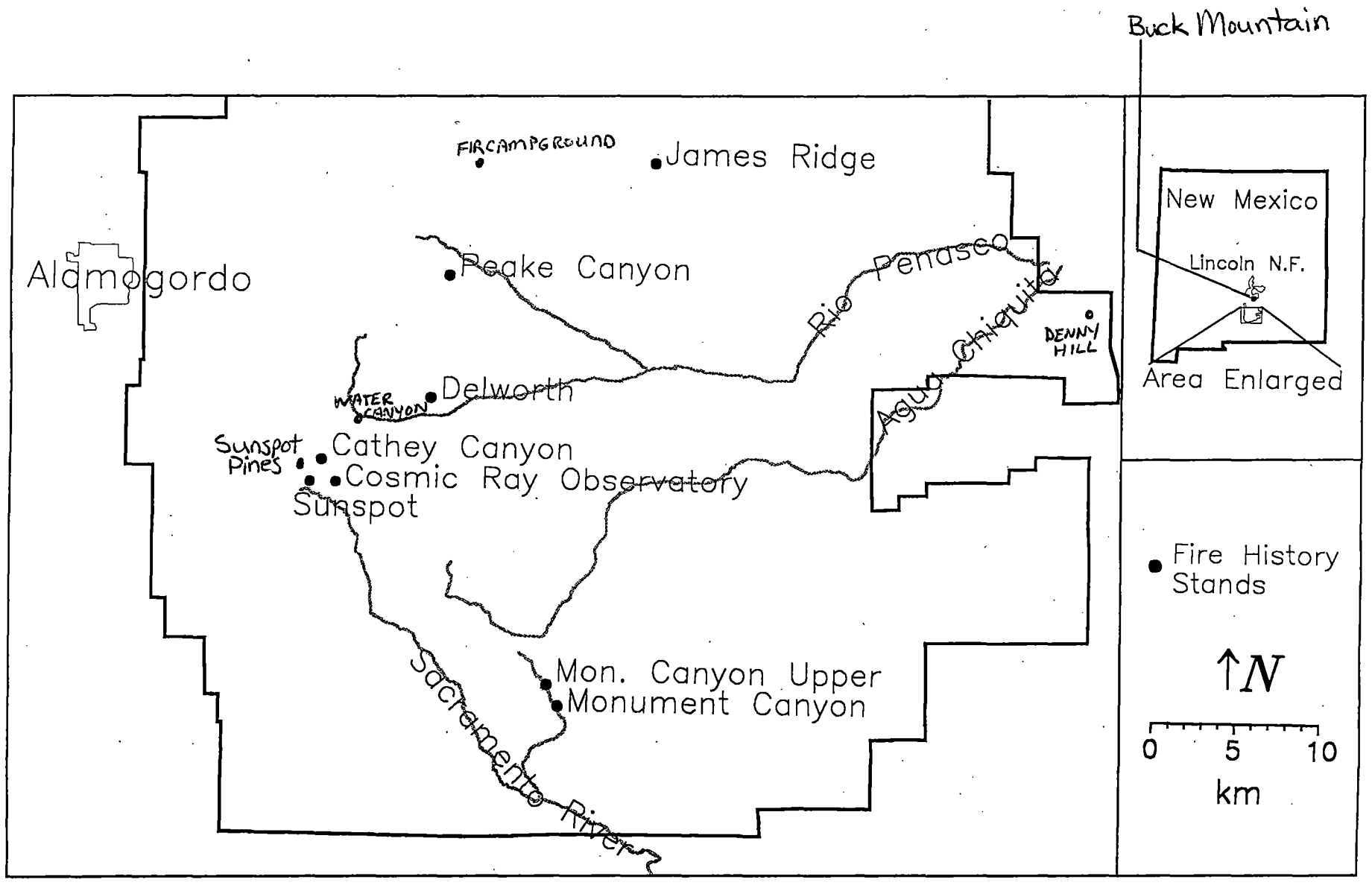
Figure 10. Regional fire years in the Sacramento Mountains. Years marked in the bottom of the figure are those fire years that occurred in at least three out of five sample areas collected.

Figure 11. Fire chronology for Fir Campground.

Figure 12. Fire chronology for Sunspot Pines.

Figure 13. Fire chronology for Water Canyon.

Figure 14. Fire chronology for Buck Mountain.


Buck Mountain
FIR CAMPGROUND
James Ridge
Alamogordo
Peake Canyon
Rio Penasco
Agua Chiquita
DENNY HILL
WATER CANYON
Delworth
Sunspot Pines
Cathey Canyon
Cosmic Ray Observatory
Sunspot
Mon. Canyon Upper
Monument Canyon
Sacramento River
New Mexico
Lincoln N.F.
Area Enlarged
Fire History Stands
N
0 5 10
km

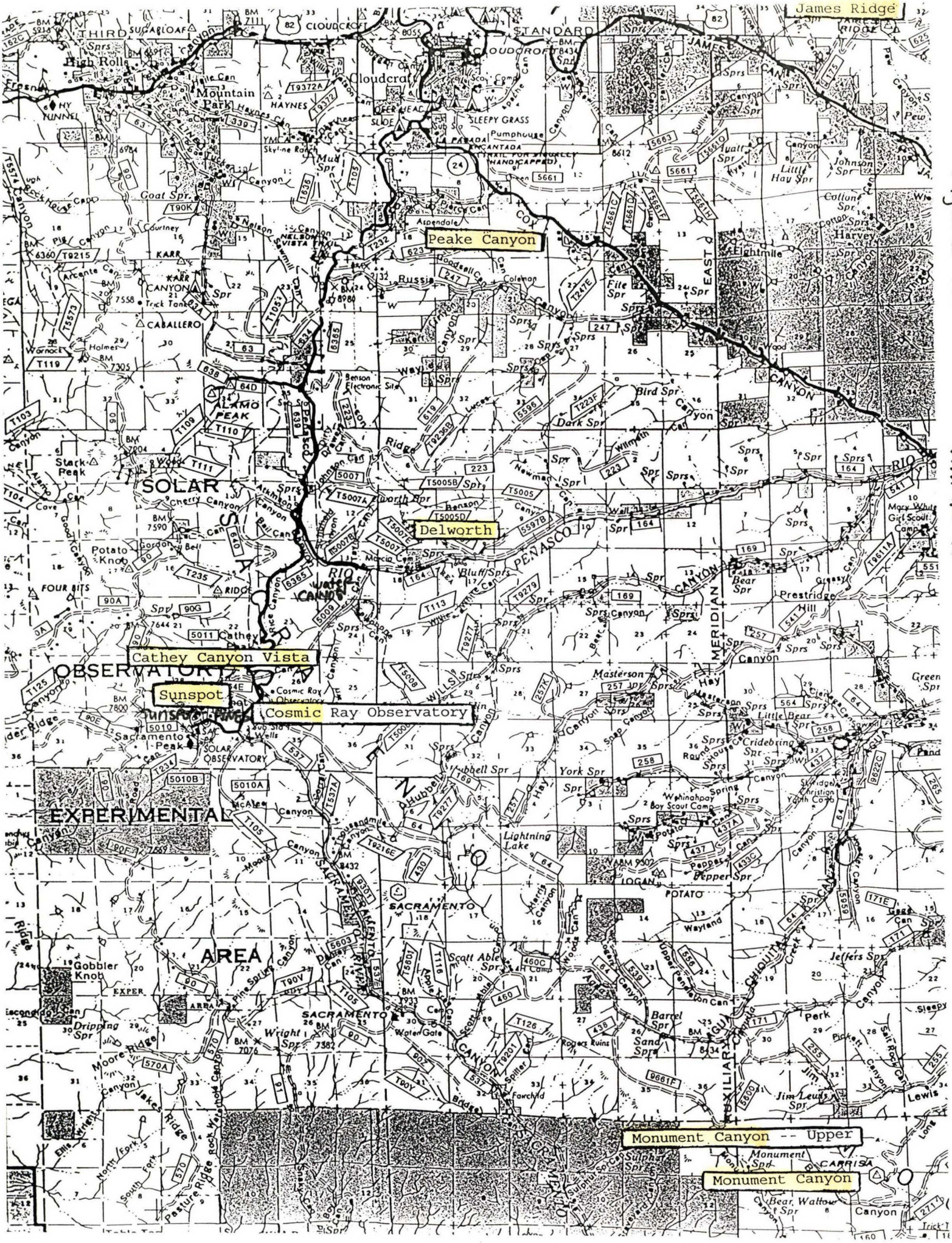

James Ridge
Peake Canyon
Delworth
Cathey Canyon Vista
Sunspot
Cosmic Ray Observatory
Monument Canyon -- Upper
Monument Canyon

Figure 2

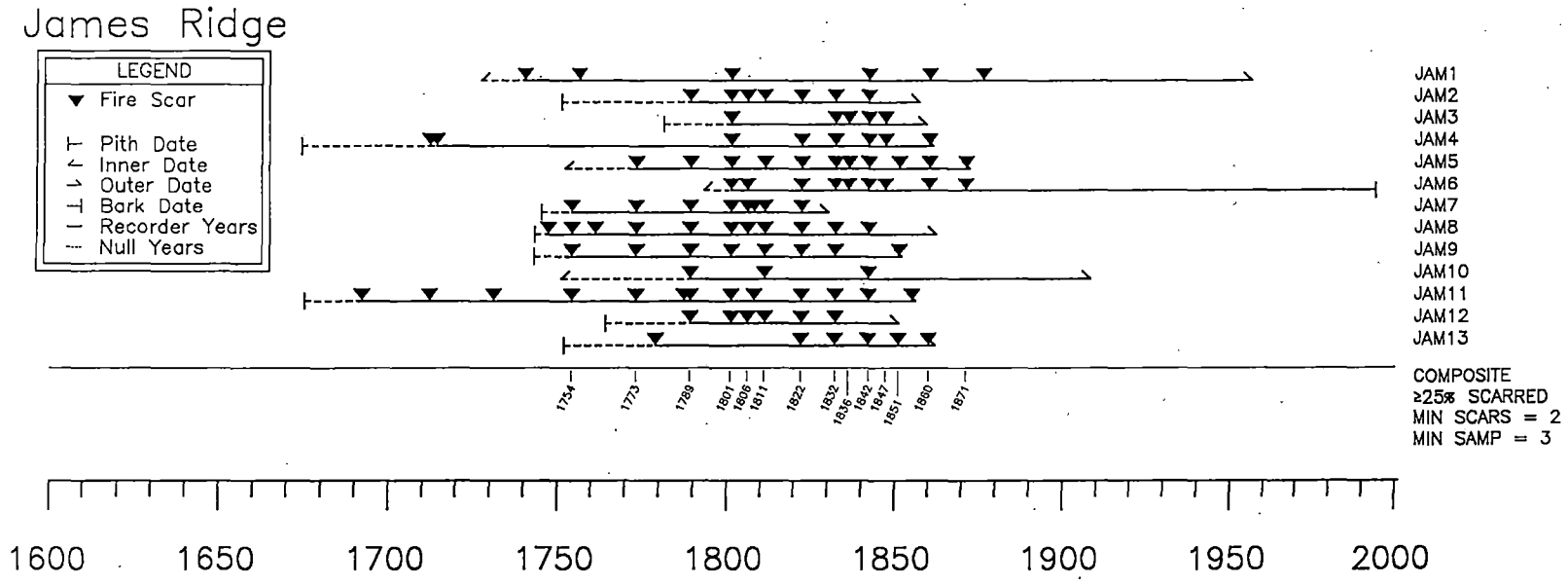

James Ridge
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
JAM1
JAM2
JAM3
JAM4
JAM5
JAM6
JAM7
JAM8
JAM9
JAM10
JAM11
JAM12
JAM13
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1754
1773
1789
1801
1806
1811
1822
1832
1836
1842
1847
1851
1860
1871
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 3

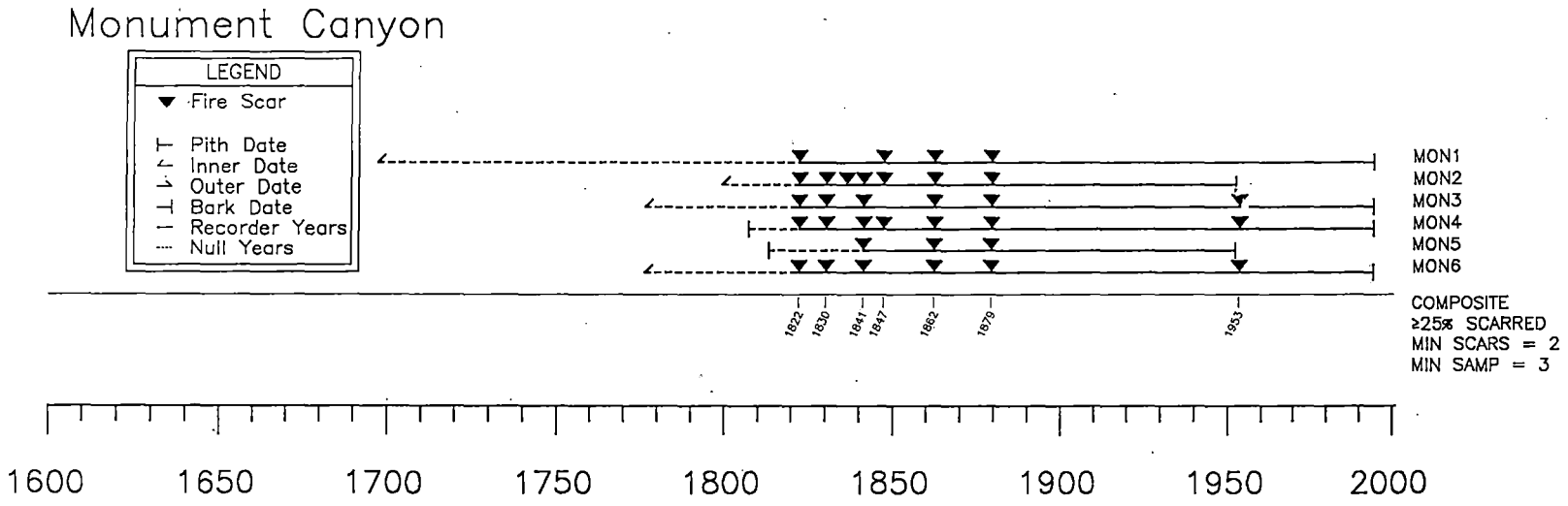

Monument Canyon
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
MON1
MON2
MON3
MON4
MON5
MON6
1822
1830
1841
1847
1862
1879
1953
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 4

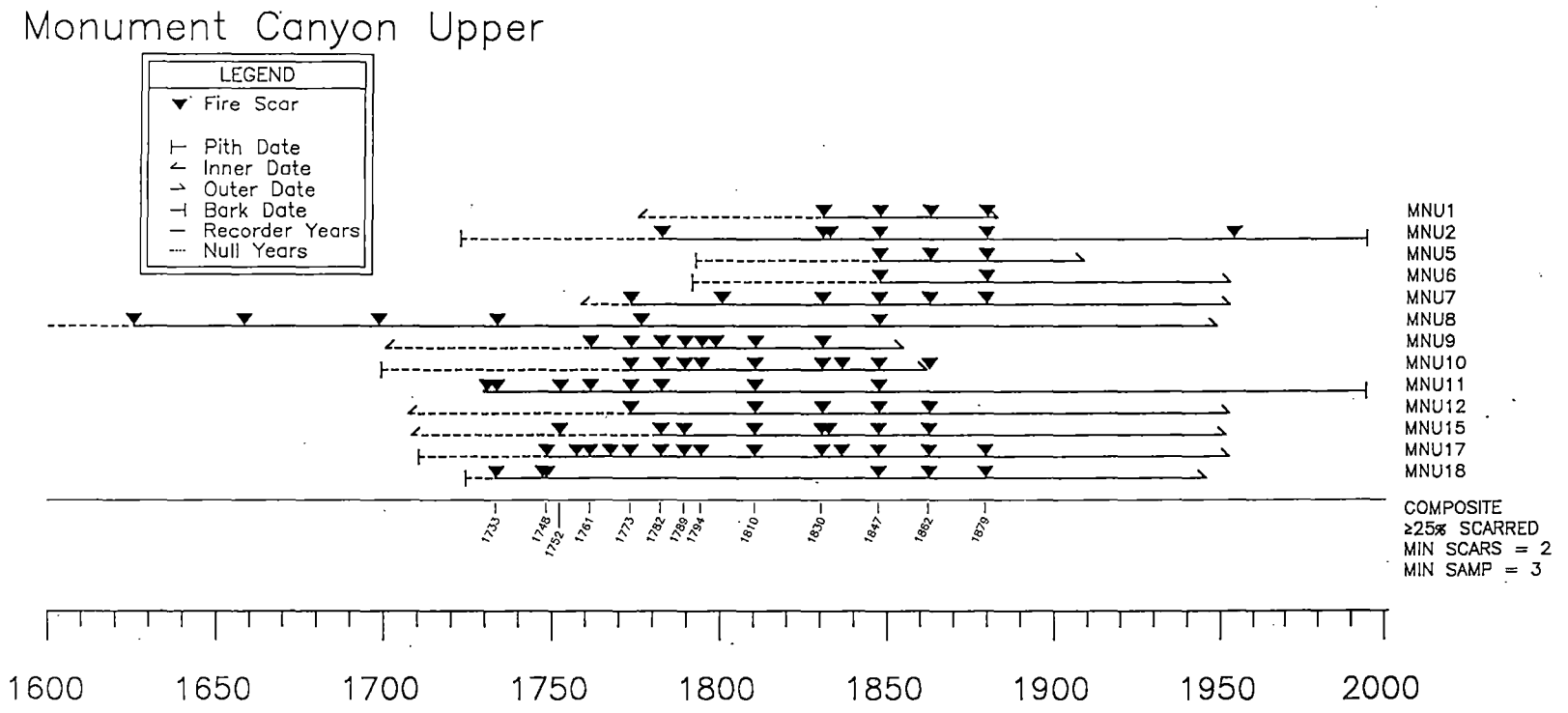

Monument Canyon Upper
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
MNU1
MNU2
MNU5
MNU6
MNU7
MNU8
MNU9
MNU10
MNU11
MNU12
MNU15
MNU17
MNU18
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1733
1748
1752
1761
1773
1782
1789
1794
1810
1830
1847
1862
1879
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 5.

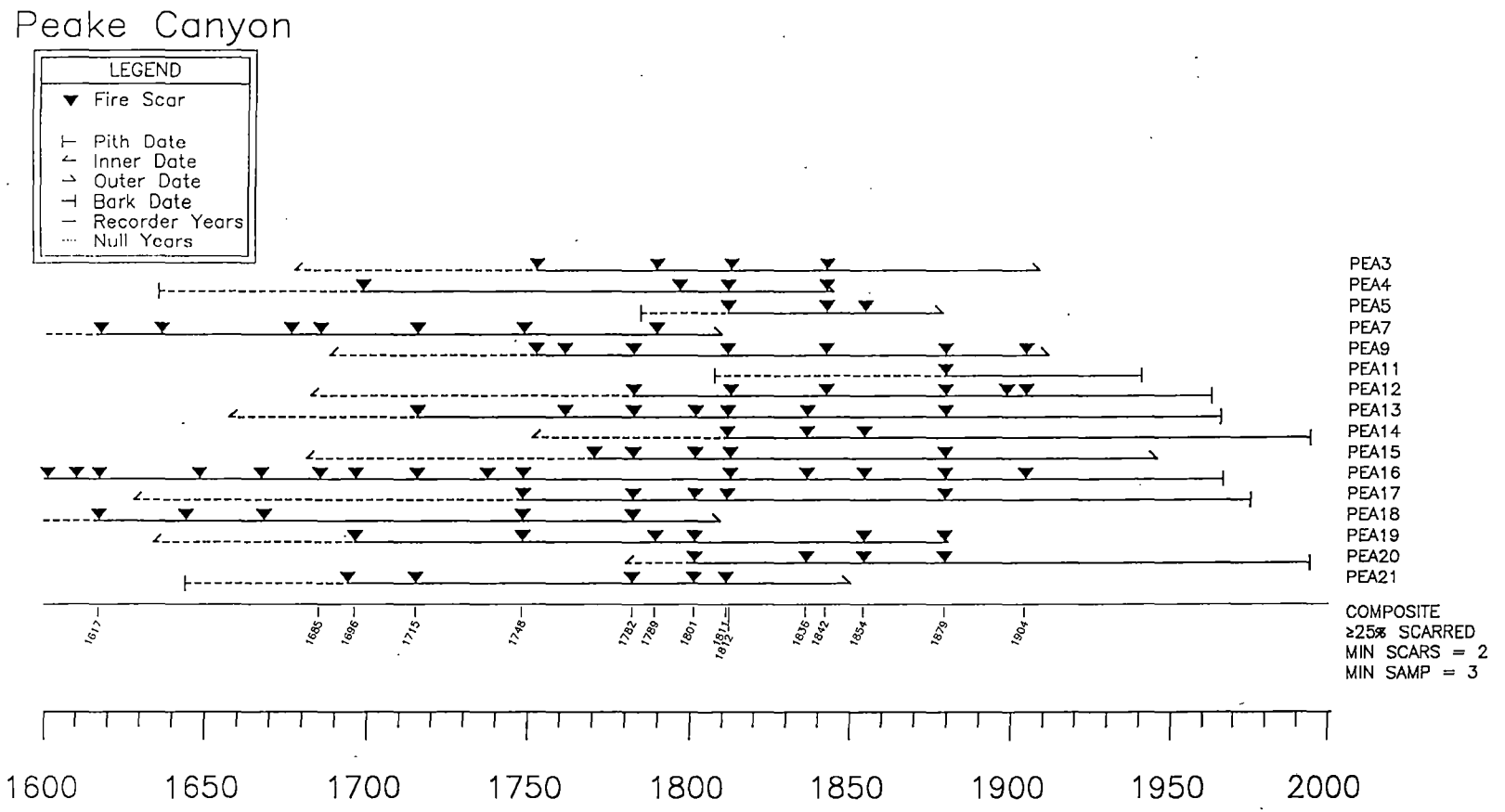

Peake Canyon
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
PEA3
PEA4
PEA5
PEA7
PEA9
PEA11
PEA12
PEA13
PEA14
PEA15
PEA16
PEA17
PEA18
PEA19
PEA20
PEA21
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1617
1685
1696
1715
1748
1782
1789
1801
1811
1836
1842
1854
1879
1904
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 6.

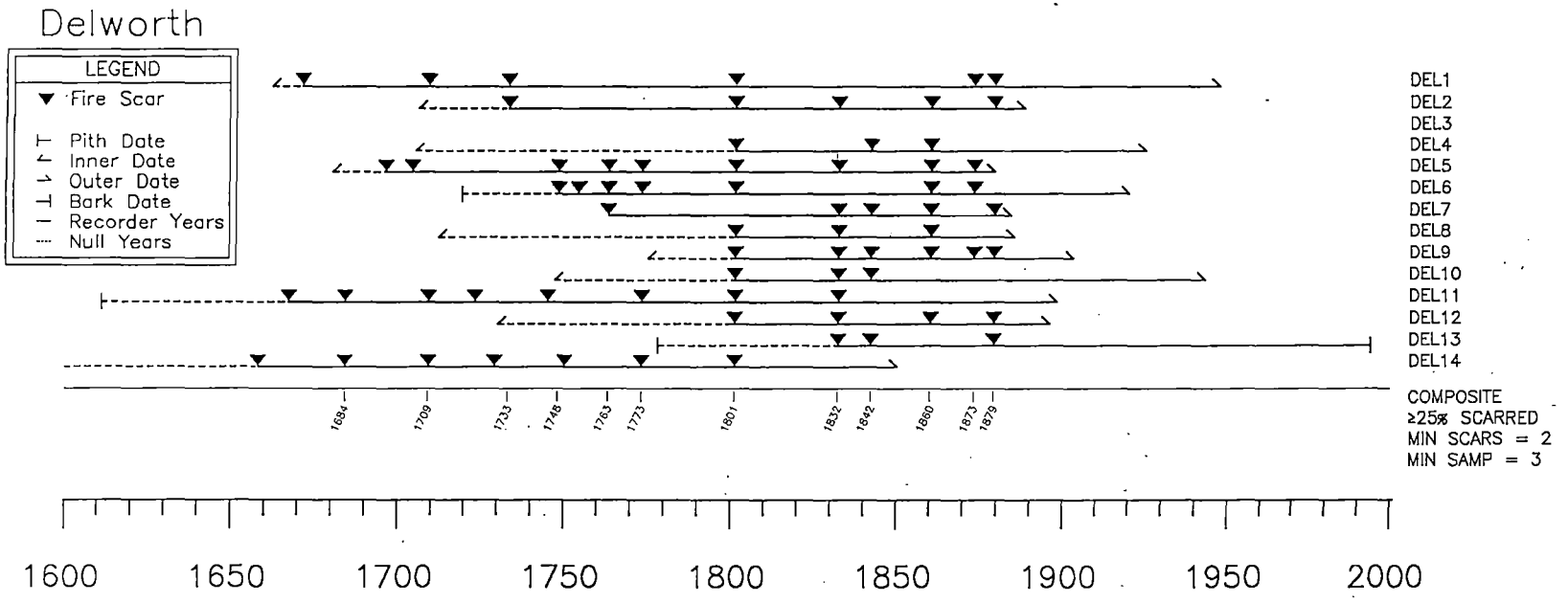

Delworth
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
DEL1
DEL2
DEL3
DEL4
DEL5
DEL6
DEL7
DEL8
DEL9
DEL10
DEL11
DEL12
DEL13
DEL14
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1684
1709
1733
1748
1763
1773
1801
1832
1842
1860
1873
1879
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 7

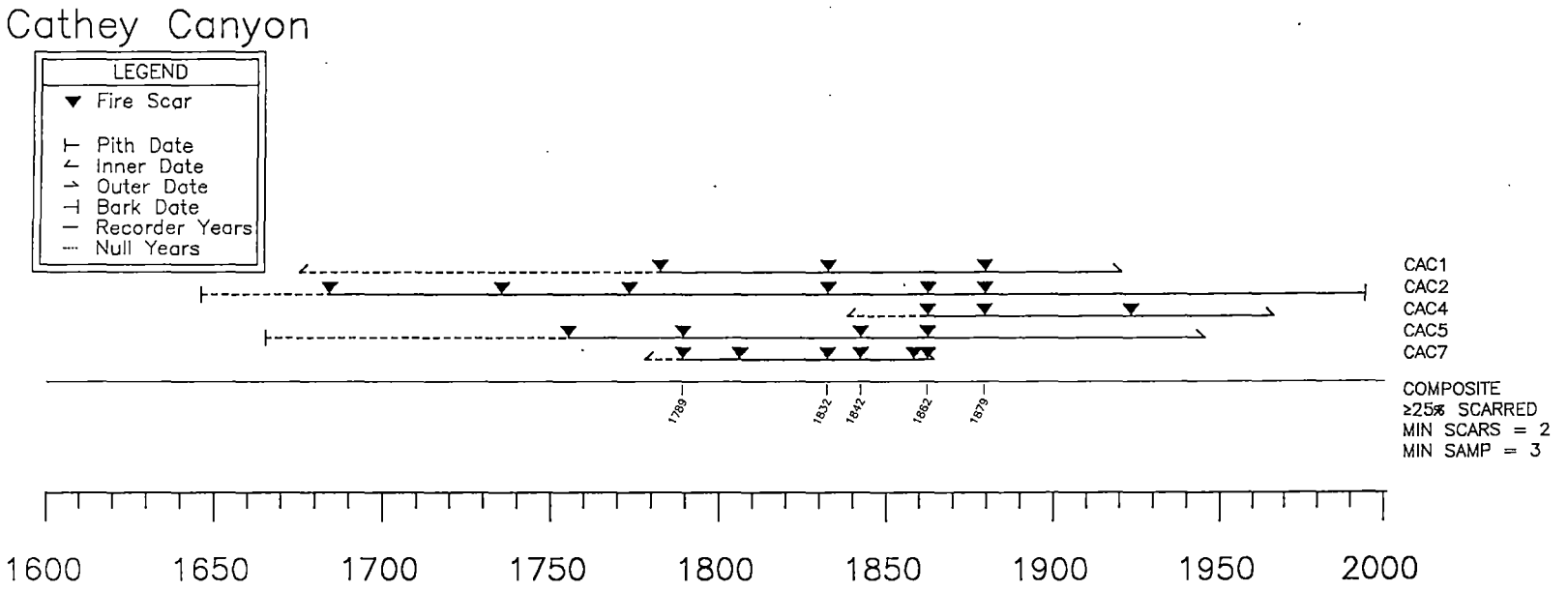

Cathey Canyon
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
CAC1
CAC2
CAC4
CAC5
CAC7
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1789
1832
1842
1862
1879
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 8

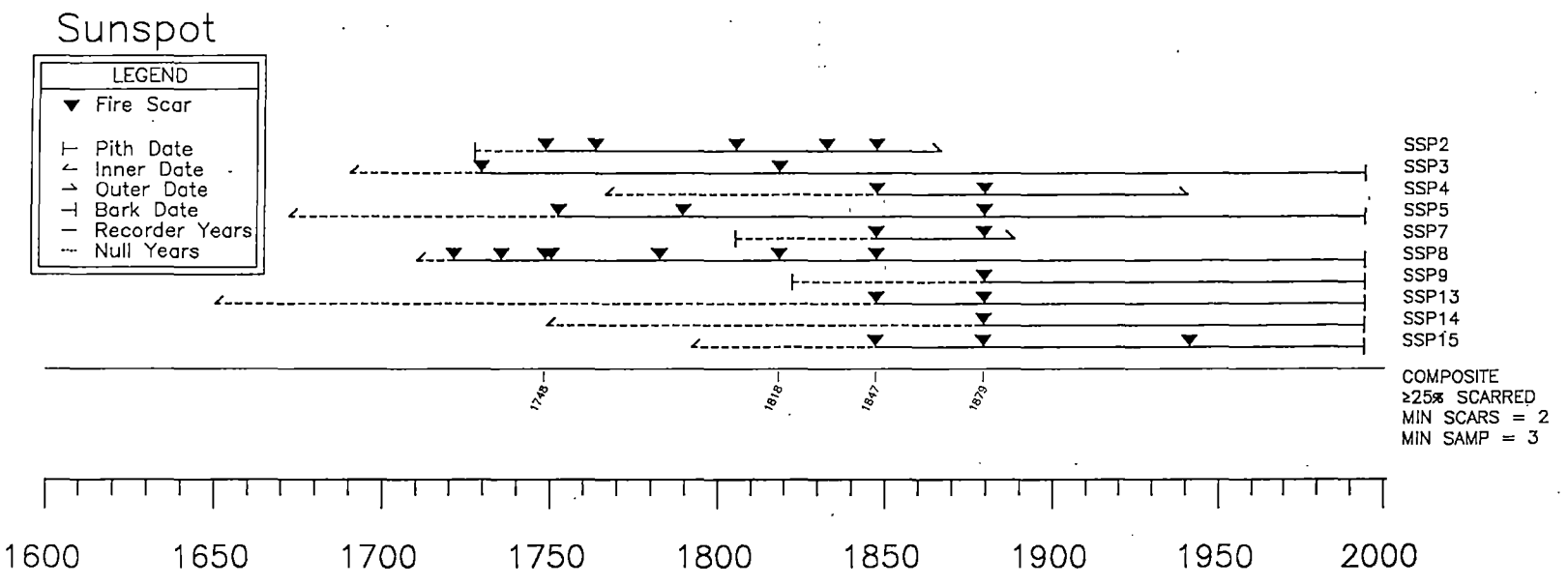

Sunspot
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
SSP2
SSP3
SSP4
SSP5
SSP7
SSP8
SSP9
SSP13
SSP14
SSP15
1748
1818
1847
1879
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 9

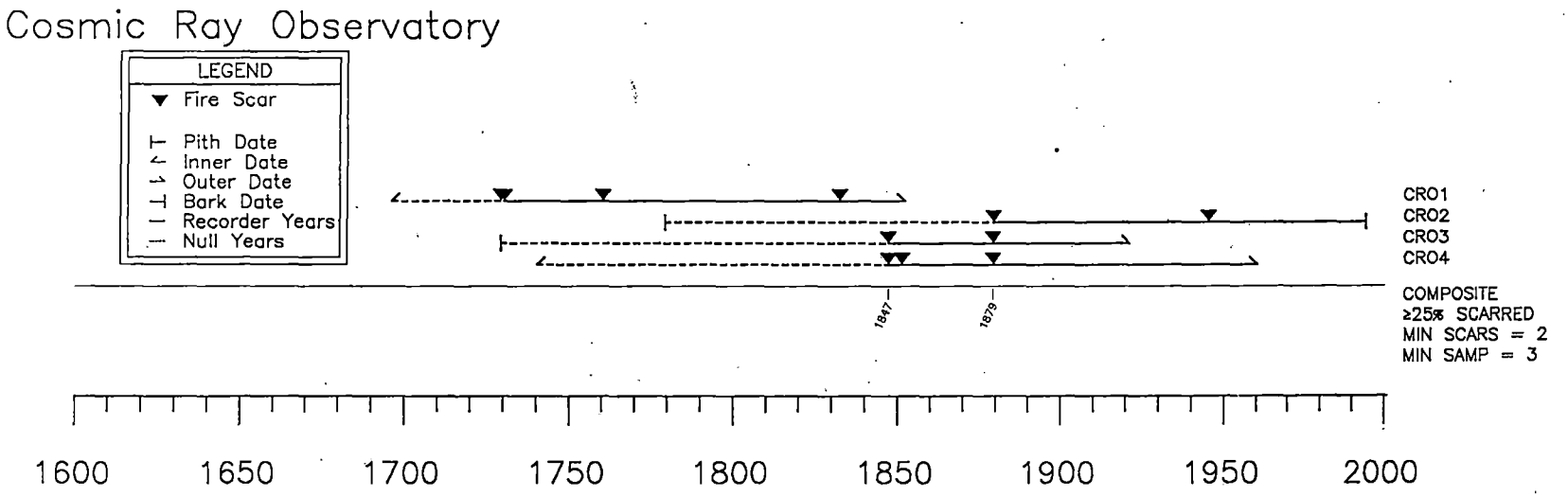

Cosmic Ray Observatory
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
CRO1
CRO2
CRO3
CRO4
COMPOSITE
≥25% SCARRED
MIN SCARS = 2
MIN SAMP = 3
1847
1879
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 10.

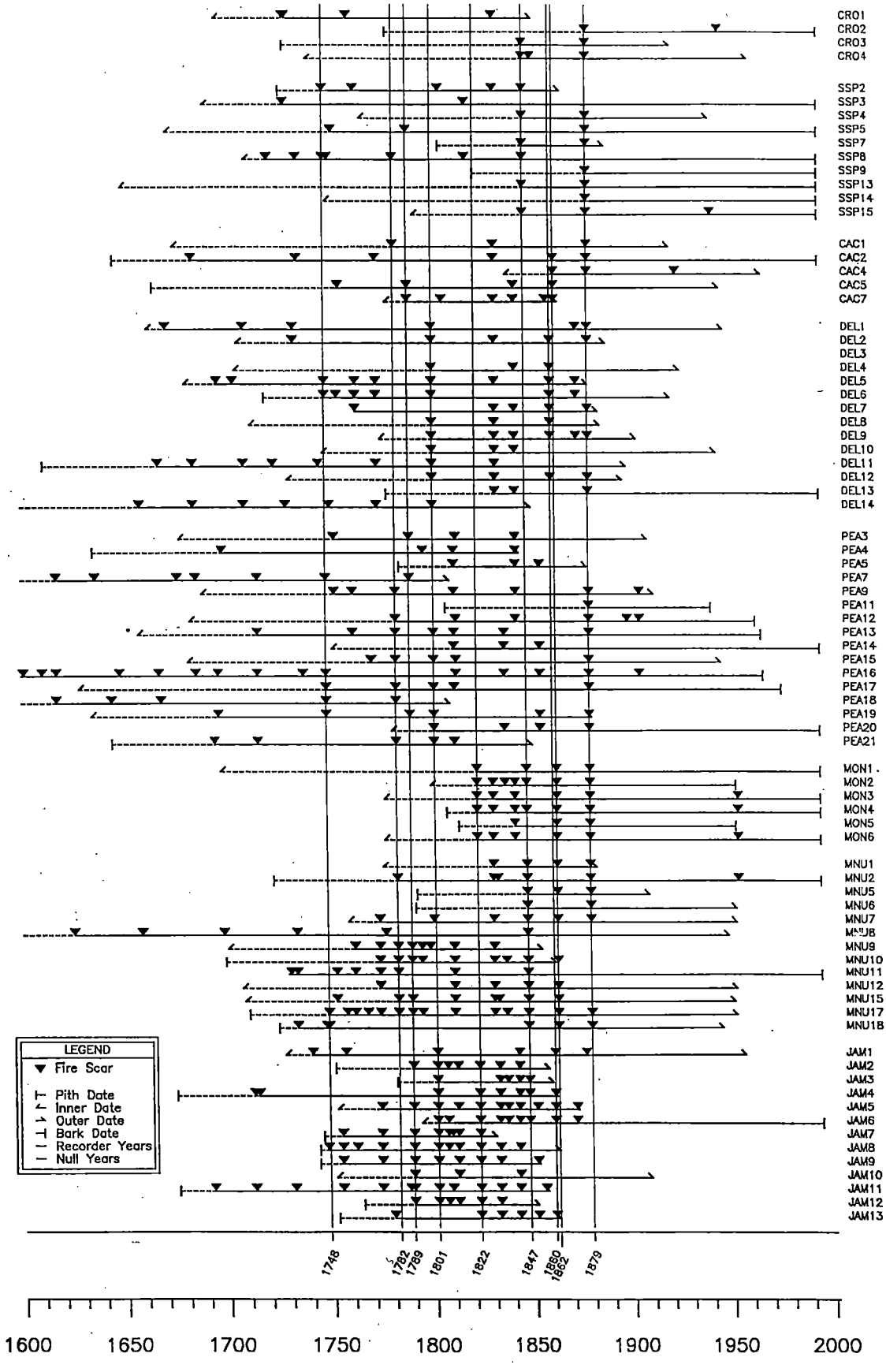

CRO1
CRO2
CRO3
CRO4
SSP2
SSP3
SSP4
SSP5
SSP7
SSP8
SSP9
SSP13
SSP14
SSP15
CAC1
CAC2
CAC4
CAC5
CAC7
DEL1
DEL2
DEL3
DEL4
DEL5
DEL6
DEL7
DEL8
DEL9
DEL10
DEL11
DEL12
DEL13
DEL14
PEA3
PEA4
PEA5
PEA7
PEA9
PEA11
PEA12
PEA13
PEA14
PEA15
PEA16
PEA17
PEA18
PEA19
PEA20
PEA21
MON1
MON2
MON3
MON4
MON5
MON6
MNU1
MNU2
MNU5
MNU6
MNU7
MNU8
MNU9
MNU10
MNU11
MNU12
MNU15
MNU17
MNU18
JAM1
JAM2
JAM3
JAM4
JAM5
JAM6
JAM7
JAM8
JAM9
JAM10
JAM11
JAM12
JAM13
LEGEND
Fire Scar
Pith Date
Inner Date
Outer Date
Bark Date
Recorder Years
Null Years
1748
1782
1789
1801
1822
1847
1860
1862
1879
1600
1650
1700
1750
1800
1850
1900
1950
2000

Figure 11 Fir Campground area 1995

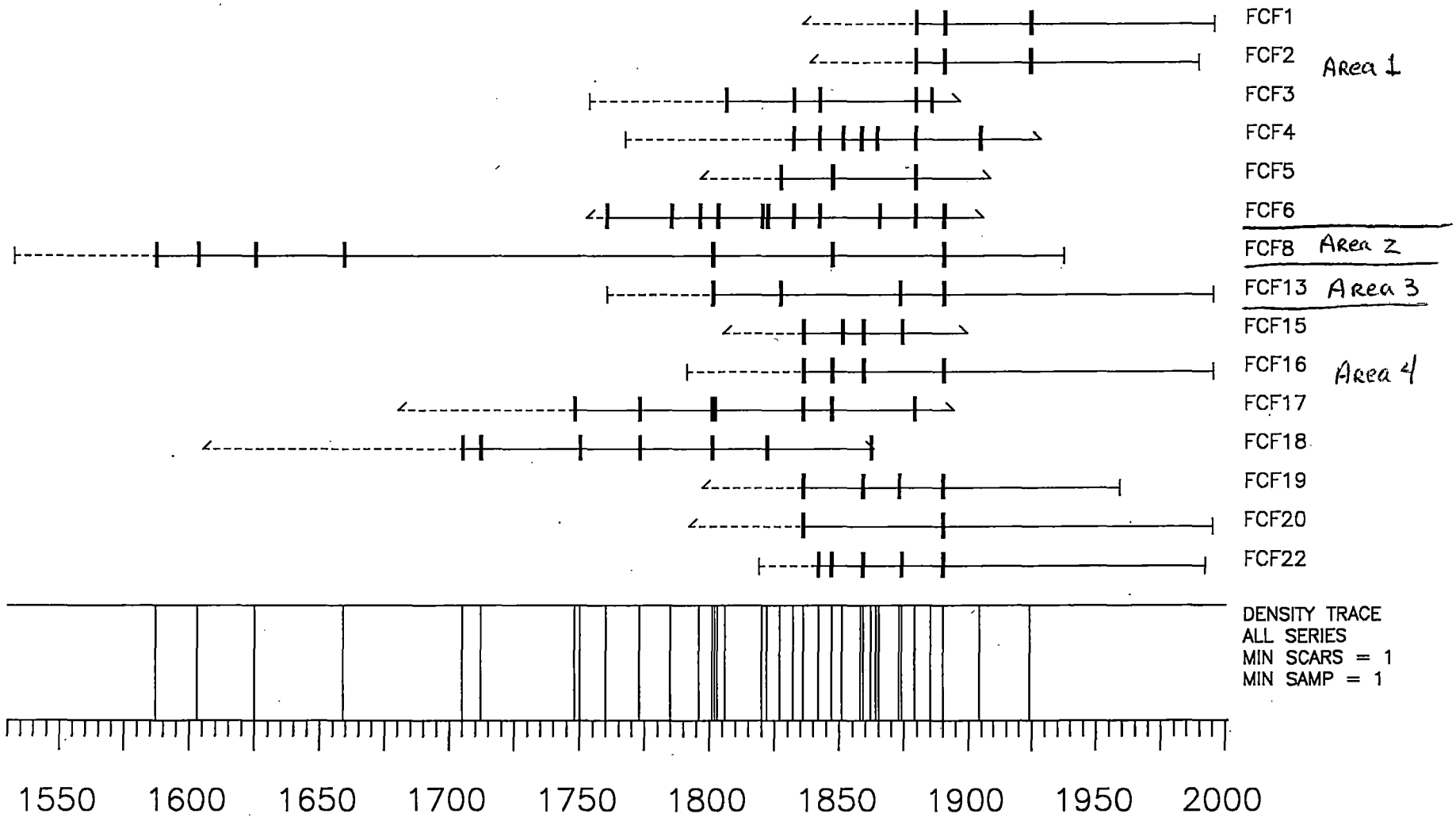


Figure 12 Sunspot Pines 1995

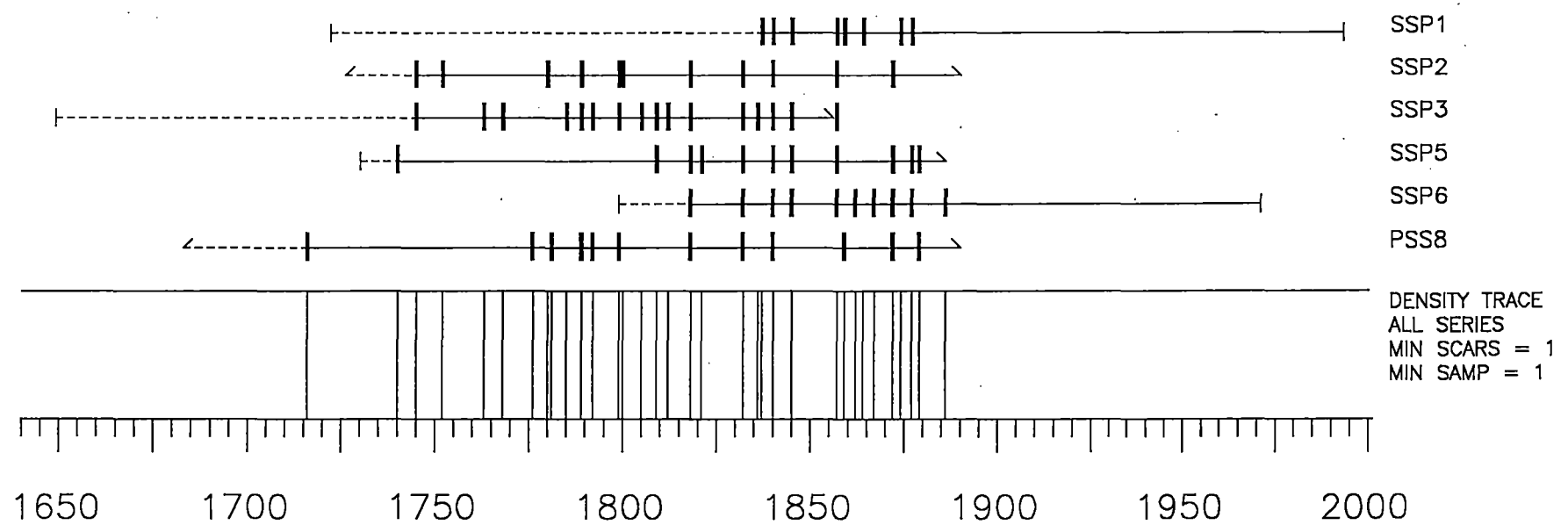


Figure 13

Water Canyon

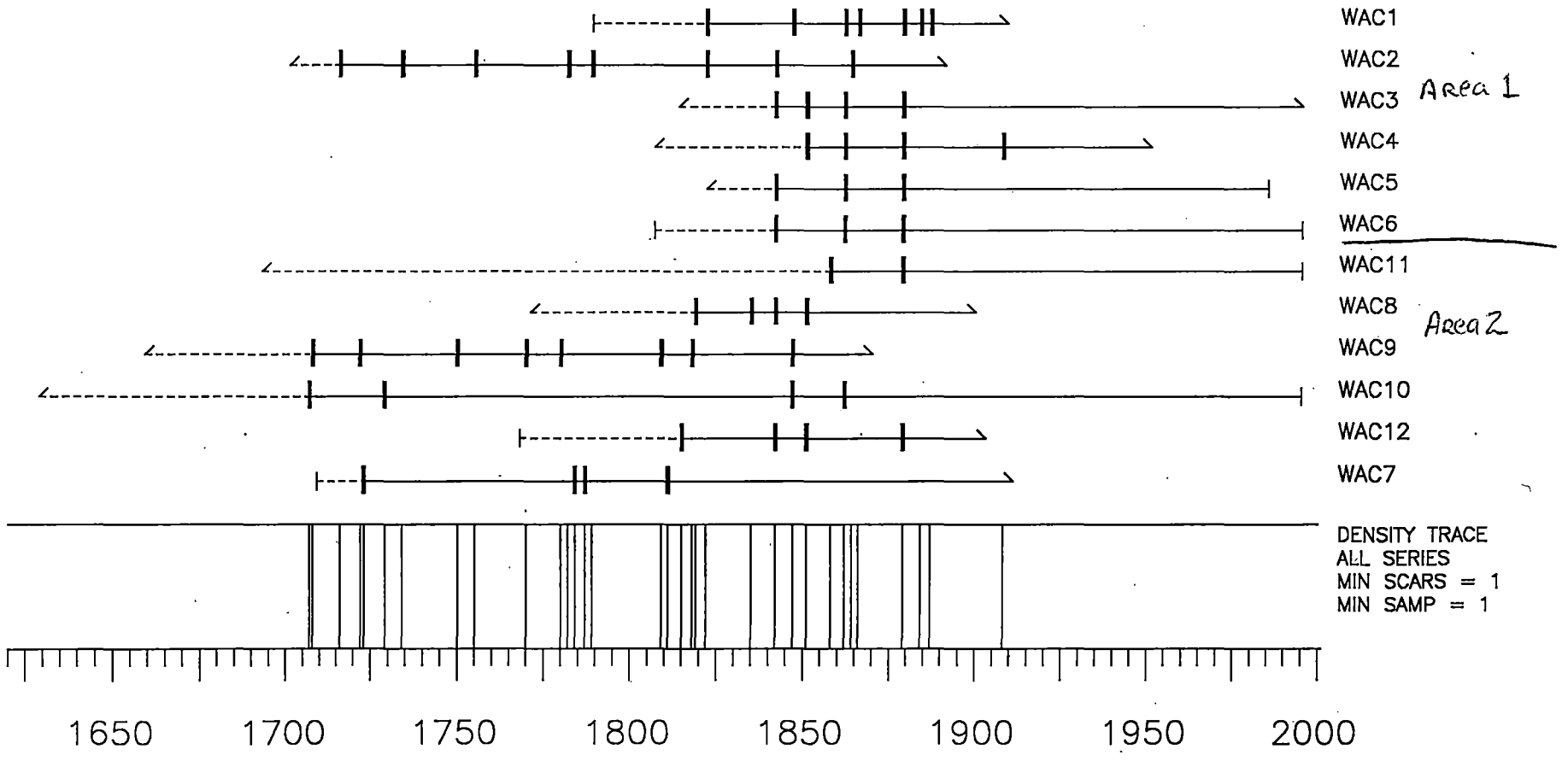


Figure 14 Buck Mountain